. EO/US
PCT/IL99/00490

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing: 15 March 2001 (15.03.01)	
International application No.: PCT/IL99/00490	Applicant's or agent's file reference: 001/01103
International filing date: 08 September 1999 (08.09.99)	Priority date:
Applicant: IDDAN, Gavriel, J. et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International preliminary Examining Authority on:

16 August 2000 (16.08.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer: J. Zahra
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992)

3882161

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
FENSTER, Paul
Fenster & Company Patent
Attorneys, Ltd.
P.O. Box 10256
49002 Petach Tikva
ISRAEL

RECEIVED
27-03-2001
FENSTER & Co.

Date of mailing (day/month/year) 15 March 2001 (15.03.01)	
Applicant's or agent's file reference 001/01103	IMPORTANT NOTICE

International application No.	International filing date (day/month/year)	Priority date (day/month/year)
PCT/IL99/00490	08 September 1999 (08.09.99)	

Applicant
3DV SYSTEMS, LTD. et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
AU,KP,KR,US

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CR,CU,CZ,DE,DK,DM,EA,EE,EP,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MD,MG,MK,MN,MW,MX,NO,NZ,OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,UA,UG,UZ,VN,YU,ZA,ZW
The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on 15 March 2001 (15.03.01) under No. WO 01/18563

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a demand for international preliminary examination must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the national phase, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer J. Zahra
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 001/01103	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/IL 99/ 00490	International filing date *(day/month/year)* 08/09/1999	(Earliest) Priority Date *(day/month/year)*
Applicant 3DV SYSTEMS, LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2a

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.
   [ ] None of the figures.

FAX: 972 3921 5383

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

FENSTER, P.
FENSTER & COMPANY PATENT
ATTORNEYS, LTD
P.O.Box 10256
Petach Tikva 49002
ISRAEL

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	10.05.2001

Applicant's or agent's file reference 001/01103	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IL99/00490	08/09/1999	08/09/1999

Applicant
3DV SYSTEMS, LTD. et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Kellerer, C Tel.+49 89 2399-2261

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 001/01103	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL99/00490	International filing date *(day/month/year)* 08/09/1999	Priority date *(day/month/year)* 08/09/1999
International Patent Classification (IPC) or national classification and IPC G01S17/02		
Applicant 3DV SYSTEMS, LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 10 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 6 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
16/08/2000	10.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Westholm, M Telephone No. +49 89 2399 2414

Form PCT/IPEA/409 (cover sheet) (January 1994)

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1-17	as originally filed			

Claims, No.:

7-34	as received on	18/08/2000	with letter of	16/08/2000
1-6	as received on	20/04/2001	with letter of	18/04/2001

Drawings, sheets:

1/5,2/5,4/5,5/5	as originally filed			
3/5	as received on	20/04/2001	with letter of	18/04/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   - ☐ restricted the claims.
   - ☒ paid additional fees.
   - ☐ paid additional fees under protest.
   - ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   - ☐ complied with.
   - ☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   - ☒ all parts.
   - ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-34
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-34
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-34
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

1. Reference is made to the following documents (numbering according to the order in the search report):

   D1: US-A-5 434 612 (NETTLETON JOHN E ET AL) 18 July 1995 (1995-07-18) cited in the application
   D2: EP-A-0 777 134 (YALESTOWN CORP NV) 4 June 1997 (1997-06-04)
   D3: WO 95 30928 A (IMAGE TECHNOLOGY INT) 16 November 1995 (1995-11-16)

2. The application lacks unity within the meaning of Rule 13 PCT for the following reasons:

2.1. The application contains the following independent claims for devices and methods:

a) Claim 1 relating to an imaging system with, among others, a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other.

b) Claim 29 relating to a gated 3D camera with, among others, at least 2 photosurfaces.

2.2. The only matter common to the two independent claims is:

a taking lens system that collects light from a scene being imaged with the optical imaging system;

Systems with these features are well known, see for example D1.

The matter common to all the independent claims is thus not novel and does therefore not constitute a general inventive concept (see PCT Guidelines, III, 7.6).

2.3. The remaining subject matter of the independent claims is:

Claim 1:

An optical imaging system comprising:

a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and

an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light; and

a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other.

Claim 29:

A gated 3D camera comprising:

a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces;

a single shutter, which when gated open enables light from the taking lens system to reach the light guide; and

a controller that controls the shutter and the photosurfaces and gates on a photosurface of the at least two photosurfaces by activating the photosurface and subsequently gating the single shutter open and gates off the photosurface by gating the single shutter closed and subsequently deactivating the photosurface and wherein the controller gates on only one photosurface at a time.

2.4. These remaining features solve problems that are clearly not related to each other.

There is therefore no unifying concept common to the remaining subject-matter of the two independent claims.

The remaining subject-matter of the two independent claims does therefore not constitute a general inventive concept (see PCT Guidelines, III, 7.6).

2.5. It is therefore considered that the application contains the following groups of systems, that are not linked to each other by any single inventive concept, and that the application therefore lacks unity within the meaning of Rule 13 PCT (see

also PCT Guidelines C-III, 7.6):

Group 1:
Claims 1-28 relating to an imaging system with, among others, a light control system that controls an amount of light from the taking lens that reaches the 3D camera independently of an amount of light from the taking lens that reaches the imaging camera.

Group 2:
Claims 29-34 relating to a gated 3D camera with, among others, at least 2 photosurfaces.

3. The following objections, of formal nature, are raised.

Rule 6.3(b) PCT is not met, since the independent claims are not in the two-part form.
If, however, the applicant is of the opinion that the two-part form would be inappropriate, then reasons therefor should be provided in the letter of reply. In addition, the applicant should ensure that it is clear from the description which features of the subject-matter of claims 1 and 29 are already known in combination from the document D1 (see the PCT Guidelines, III-2.3a).

Rule 6.2(b) PCT is not met, since reference signs are missing in the claims. This applies to both the preamble and the characterising portion.

4. Claims 1-34 are considered to fulfil the requirements of Article 33 PCT.

4.1. Claim 1:

The closest prior art document is considered to be D1.

D1 discloses
An optical imaging system comprising:
a taking lens system that collects light from a scene being imaged with the optical imaging system;
a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light.

The claimed system differs from this prior art by the following features:

(a) an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light; and

(b) a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other

These differences result in a system that combines a 3D camera and an imaging camera with only one taking lens.

The problem to be solved by the invention is therefore to simplify the optical system of D1.

It is not obvious to solve this problem with the features (a) and (b) mentioned above.

None of the documents cited in the International Search Report discloses the combination of an imaging camera and a 3D camera using a same single taking lens for both cameras.
D2 discloses a combination of an imaging camera and a 3D camera, but with different taking lenses. The other documents cited in the International Search Report do not disclose the combination of an imaging camera and a 3D camera at all.

It is not obvious to use a single taking lens for an imaging system comprising a 3D camera combined with an imaging camera. Illumination of a scene for imaging with a 3D camera is generally quite different from illumination of a scene for

imaging with an imaging camera. As a result, light gathering capacity required of a taking lens used with a 3D camera is generally different from light gathering capacity required of a taking lens used with an imaging camera. There is usually ample light available for imaging a scene with an imaging camera. On the other hand a quantity of light available for imaging with a 3D camera is generally small. For example, light for imaging a scene using a 3D camera is often supplied by a laser. For practical and safety reasons the output power of the laser is usually limited. As a result, a taking lens used with a 3D camera that images a scene must generally be set to a substantially lower f-number than an f-number setting for a taking lens used with an imaging camera that images the scene. The antagonistic f-number requirements of a 3D camera and an imaging camera teach away from using a single taking lens for both a 3D camera and an imaging camera.

Claim 1 resolves the antagonism by the limitation of "a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other". None of the documents cited in the International Search Report discloses this feature.

4.2. Claim 29:

The closest prior art document is considered to be D1.

D1 discloses
a gated 3D camera comprising:
a taking lens system that collects light from a scene imaged with the 3D camera;
at least 2 photosurfaces;
a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces.

The claimed device differs from this prior art by the following features:

(a) a single shutter, which when gated open enables light from the taking lens system to reach the light guide; and

(b) a controller that controls the shutter and the photosurfaces and gates on a photosurface of the at least two photosurfaces by activating the photosurface and subsequently gating the single shutter open and gates off the photosurface by

gating the single shutter closed and subsequently deactivating the photosurface and wherein the controller gates on only one photosurface at a time.

With these distinguishing features, the claimed device can use one single shutter for fast gating of at least two photosurfaces subsequently. These differences do thus result in a device in which the advantages of a device with one shutter per photosurface are obtained without the constructional complexity of physically providing one shutter for each photosurface.

The problem to be solved by the invention is therefore to simplify the device of D1.

It is not obvious to solve this problem with the features (a) and (b) mentioned above.

None of the documents cited in the International Search Report discloses the use of one single shutter for subsequent gating of at least two photosurfaces.
D3 (page 12-14 and figures 9-11) discloses a camera in which one single shutter is used for gating of three photosurfaces (feature "(a)"). The gating is however not performed for one photosurface at a time, but simultaneously for all the photosurfaces.

The other documents cited in the International Search Report do not disclose sharing of a single shutter between several photosurfaces at all.

CLAIMS

1. An optical imaging system comprising:

a taking lens system that collects light from a scene being imaged with the optical imaging system;

a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and

an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light; and

a light control system that controls an amount of light from the taking lens that reaches at least one of the 3D camera and the imaging camera without affecting an amount of light that reaches the other of the 3D camera and the imaging camera.

2. An optical imaging system according to claim 1 wherein the 3D camera and the imaging camera are boresighted with the taking lens system.

3. An optical imaging system according to claim 1 or claim 2 wherein the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are homologous.

4. An optical imaging system according to any of the preceding claims wherein the light control system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera.

5. An optical imaging system according to claim 4 wherein the light controller comprises an iris.

6. An optical imaging system according to claim 4 wherein the light controller comprises a neutral density filter.

7. An optical imaging system according to any of the preceding claims wherein the light control system comprises a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system.

8. An optical imaging system according to claim 7 wherein the light controller that controls the amount of light collected by the taking lens system that enters the imaging system comprises an iris.

9. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera.

10. An optical imaging system according to claim 9 wherein the light controller that controls the amount of light from the taking lens system that reaches the 3D camera comprises an iris.

11. An optical imaging system according to any of the preceding claims wherein the 3D camera is a gated 3D camera.

12. An optical imaging system according to claim 11 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the optical imaging system.

13. An optical imaging system according to claim 12 wherein the pulsed light source radiates IR light.

14. An optical imaging system according to any of claims 11 - 13 wherein the 3D camera comprises at least 2 photosurfaces.

15. An optical imaging system according to claim 14 wherein the 3D camera comprises a light guide that receives light from the taking lens system and directs portions of the light that it receives to each of the at least two photosurfaces.

16. An optical imaging system according to claim 15 and comprising a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

17. An optical imaging system according to claim 16 and comprising a controller that gates the single shutter open and closed.

18. An optical imaging system according to claim 17 wherein the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon.

19. An optical imaging system according to claim 18 wherein each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

20. An optical imaging system according to claim 19 wherein the at least two photosurfaces comprises three photosurfaces.

21. An optical imaging system according to claim 20 wherein following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and wherein the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

22. An optical imaging system according to claim 21 wherein following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and wherein the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

23. An optical imaging system according to claim 22 wherein following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and wherein the controller controls the gate width and timing of the third gate so that during the third gate substantially all

light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

24. An optical imaging system according to any of claims 15-23 wherein the light guide is a three-way prism.

25. An optical imaging system according to any of claims 1 - 24 and comprising a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

26. An optical imaging system according to any of claims 7 - 23 wherein the light guide is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

27. An optical imaging system according to any of the preceding claims wherein the imaging camera comprises a color camera.

28. An optical imaging system according to any of claims 1 - 24 wherein the imaging camera is a color camera comprising separate R, G and B photosurfaces and comprising a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

29. A gated 3D camera comprising:

a taking lens system that collects light from a scene imaged with the 3D camera;

at least 2 photosurfaces;

a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces;

a single shutter, which when gated open enables light from the taking lens system to reach the light guide; and

a controller that controls the shutter and the photosurfaces and gates on a photosurface of the at least two photosurfaces by activating the photosurface and subsequently gating the single shutter open and gates off the photosurface by gating the single shutter closed and

subsequently deactivating the photosurface and wherein the controller gates on only one photosurface at a time.

30. A 3D camera according to claim 29 wherein the at least two photosurfaces comprises three photosurfaces.

31. A 3D camera according to claim 30 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the 3D camera.

32. A 3D camera according to claim 31 wherein following at least one time at which a light pulse in the train of light pulses is radiated, the controller gates on a first photosurface of the three photosurfaces for a first gate period which is timed so that light reflected from the light pulse by a region in the scene is registered by the first photosurface.

33. A 3D camera according to claim 32 wherein following at least one time at which a light pulse in the train of light pulses is radiated, the controller gates on a second one of the three photosurfaces for a second gate period which is timed so that during the second gate no light from the light pulse reflected by the region is registered by the second photosurface.

34. A 3D camera according to claim 33 wherein following at least one time at which a light pulse in the train of light pulses is radiated, the controller gates on a third one of the photosurfaces for a third gate period and which is timed and has a gate width so that during the third gate substantially all light from the light pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

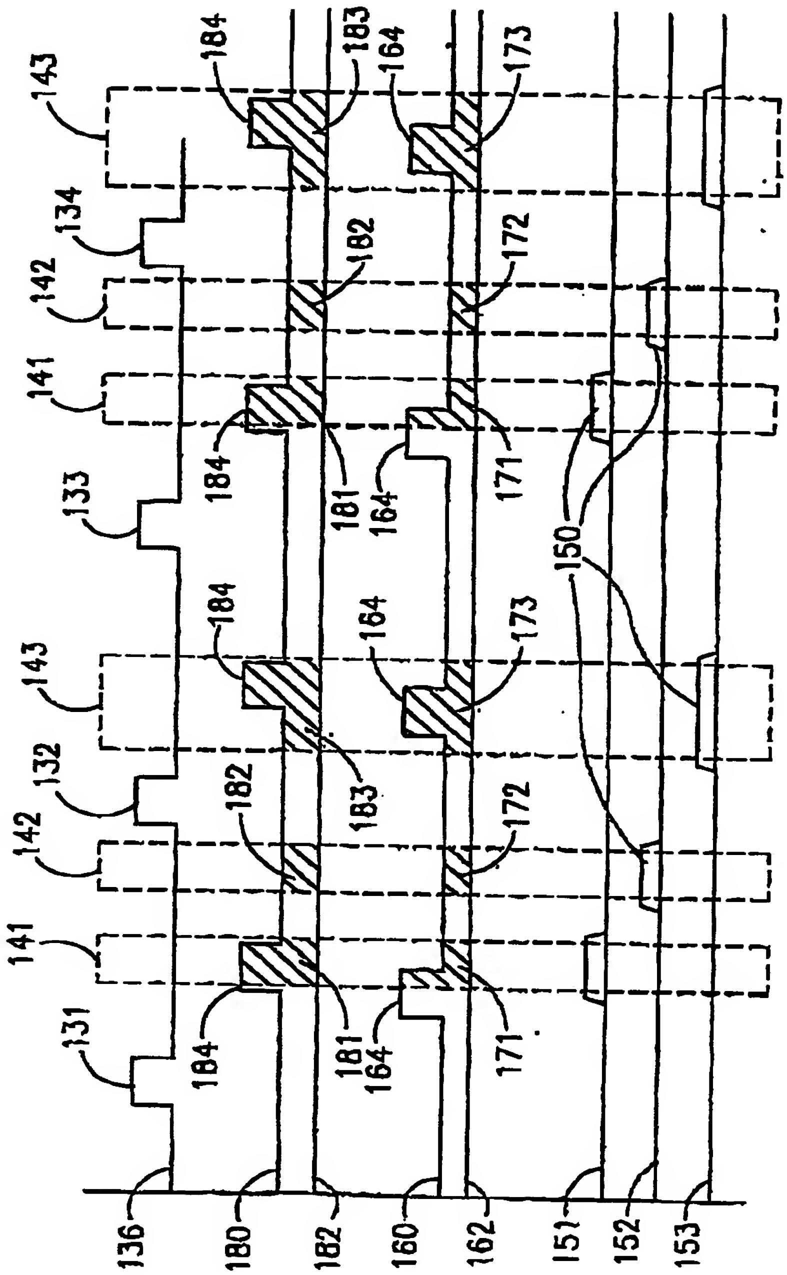

FIG.2B

AMENDED SHEET

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
FENSTER & COMPANY PATENT
ATTORNEYS, LTD
Attn. FENSTER, P.
P.O.Box 10256
Petach Tikva 49002
ISRAEL

RECEIVED
22-05-2000
FENSTER & Co.

	Date of mailing (*day/month/year*) 17/05/2000
Applicant's or agent's file reference 001/01103	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IL 99/00490	International filing date (*day/month/year*) 08/09/1999
Applicant 3DV SYSTEMS, LTD. et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within 20 months from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Eric Walsh

Form PCT/ISA/220 (July 1998)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 001/01103	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/IL 99/00490	International filing date *(day/month/year)* 08/09/1999	(Earliest) Priority Date *(day/month/year)*
Applicant 3DV SYSTEMS, LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2a

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

REC'D 20 JUN 2001
WIPO PCT

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 001/01103	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL99/00490	International filing date (*day/month/year*) 08/09/1999	Priority date (*day/month/year*) 08/09/1999
International Patent Classification (IPC) or national classification and IPC G01S17/02		
Applicant 3DV SYSTEMS, LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 10 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 6 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☒ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
16/08/2000	10.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Westholm, M Telephone No. +49 89 2399 2414

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IL99/00490

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1-17	as originally filed			

Claims, No.:

7-34	as received on	18/08/2000	with letter of	16/08/2000
1-6	as received on	20/04/2001	with letter of	18/04/2001

Drawings, sheets:

1/5,2/5,4/5,5/5	as originally filed			
3/5	as received on	20/04/2001	with letter of	18/04/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☒ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-34
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-34
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-34
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

1. Reference is made to the following documents (numbering according to the order in the search report):

   D1: US-A-5 434 612 (NETTLETON JOHN E ET AL) 18 July 1995 (1995-07-18) cited in the application
   D2: EP-A-0 777 134 (YALESTOWN CORP NV) 4 June 1997 (1997-06-04)
   D3: WO 95 30928 A (IMAGE TECHNOLOGY INT) 16 November 1995 (1995-11-16)

2. The application lacks unity within the meaning of Rule 13 PCT for the following reasons:

2.1. The application contains the following independent claims for devices and methods:

a) Claim 1 relating to an imaging system with, among others, a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other.

b) Claim 29 relating to a gated 3D camera with, among others, at least 2 photosurfaces.

2.2. The only matter common to the two independent claims is:

a taking lens system that collects light from a scene being imaged with the optical imaging system;

Systems with these features are well known, see for example D1.

The matter common to all the independent claims is thus not novel and does therefore not constitute a general inventive concept (see PCT Guidelines, III, 7.6).

2.3. The remaining subject matter of the independent claims is:

Claim 1:
An optical imaging system comprising:
a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and
an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light; and
a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other.

Claim 29:
A gated 3D camera comprising:
a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces;
a single shutter, which when gated open enables light from the taking lens system to reach the light guide; and
a controller that controls the shutter and the photosurfaces and gates on a photosurface of the at least two photosurfaces by activating the photosurface and subsequently gating the single shutter open and gates off the photosurface by gating the single shutter closed and subsequently deactivating the photosurface and wherein the controller gates on only one photosurface at a time.

2.4. These remaining features solve problems that are clearly not related to each other.

There is therefore no unifying concept common to the remaining subject-matter of the two independent claims.

The remaining subject-matter of the two independent claims does therefore not constitute a general inventive concept (see PCT Guidelines, III, 7.6).

2.5. It is therefore considered that the application contains the following groups of systems, that are not linked to each other by any single inventive concept, and that the application therefore lacks unity within the meaning of Rule 13 PCT (see

also PCT Guidelines C-III, 7.6):

Group 1:
Claims 1-28 relating to an imaging system with, among others, a light control system that controls an amount of light from the taking lens that reaches the 3D camera independently of an amount of light from the taking lens that reaches the imaging camera.

Group 2:
Claims 29-34 relating to a gated 3D camera with, among others, at least 2 photosurfaces.

3. The following objections, of formal nature, are raised.

Rule 6.3(b) PCT is not met, since the independent claims are not in the two-part form.
If, however, the applicant is of the opinion that the two-part form would be inappropriate, then reasons therefor should be provided in the letter of reply. In addition, the applicant should ensure that it is clear from the description which features of the subject-matter of claims 1 and 29 are already known in combination from the document D1 (see the PCT Guidelines, III-2.3a).

Rule 6.2(b) PCT is not met, since reference signs are missing in the claims. This applies to both the preamble and the characterising portion.

4. Claims 1-34 are considered to fulfil the requirements of Article 33 PCT.

4.1. Claim 1:

The closest prior art document is considered to be D1.

D1 discloses
An optical imaging system comprising:
a taking lens system that collects light from a scene being imaged with the optical imaging system;
a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light.

The claimed system differs from this prior art by the following features:

(a) an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light; and

(b) a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other

These differences result in a system that combines a 3D camera and an imaging camera with only one taking lens.

The problem to be solved by the invention is therefore to simplify the optical system of D1.

It is not obvious to solve this problem with the features (a) and (b) mentioned above.

None of the documents cited in the International Search Report discloses the combination of an imaging camera and a 3D camera using a same single taking lens for both cameras.
D2 discloses a combination of an imaging camera and a 3D camera, but with different taking lenses. The other documents cited in the International Search Report do not disclose the combination of an imaging camera and a 3D camera at all.

It is not obvious to use a single taking lens for an imaging system comprising a 3D camera combined with an imaging camera. Illumination of a scene for imaging with a 3D camera is generally quite different from illumination of a scene for

imaging with an imaging camera. As a result, light gathering capacity required of a taking lens used with a 3D camera is generally different from light gathering capacity required of a taking lens used with an imaging camera. There is usually ample light available for imaging a scene with an imaging camera. On the other hand a quantity of light available for imaging with a 3D camera is generally small. For example, light for imaging a scene using a 3D camera is often supplied by a laser. For practical and safety reasons the output power of the laser is usually limited. As a result, a taking lens used with a 3D camera that images a scene must generally be set to a substantially lower f-number than an f-number setting for a taking lens used with an imaging camera that images the scene. The antagonistic f-number requirements of a 3D camera and an imaging camera teach away from using a single taking lens for both a 3D camera and an imaging camera.

Claim 1 resolves the antagonism by the limitation of "a light control system that controls an amount of light from the taking lens that reaches the 3D camera and the imaging camera independently of each other". None of the documents cited in the International Search Report discloses this feature.

4.2. Claim 29:

The closest prior art document is considered to be D1.

D1 discloses
a gated 3D camera comprising:
a taking lens system that collects light from a scene imaged with the 3D camera;
at least 2 photosurfaces;
a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces.

The claimed device differs from this prior art by the following features:

(a) a single shutter, which when gated open enables light from the taking lens system to reach the light guide; and

(b) a controller that controls the shutter and the photosurfaces and gates on a photosurface of the at least two photosurfaces by activating the photosurface and subsequently gating the single shutter open and gates off the photosurface by

gating the single shutter closed and subsequently deactivating the photosurface and wherein the controller gates on only one photosurface at a time.

With these distinguishing features, the claimed device can use one single shutter for fast gating of at least two photosurfaces subsequently. These differences do thus result in a device in which the advantages of a device with one shutter per photosurface are obtained without the constructional complexity of physically providing one shutter for each photosurface.

The problem to be solved by the invention is therefore to simplify the device of D1.

It is not obvious to solve this problem with the features (a) and (b) mentioned above.

None of the documents cited in the International Search Report discloses the use of one single shutter for subsequent gating of at least two photosurfaces.
D3 (page 12-14 and figures 9-11) discloses a camera in which one single shutter is used for gating of three photosurfaces (feature "(a)"). The gating is however not performed for one photosurface at a time, but simultaneously for all the photosurfaces.

The other documents cited in the International Search Report do not disclose sharing of a single shutter between several photosurfaces at all.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 March 2001 (15.03.2001)

PCT

(10) International Publication Number
WO 01/18563 A1

(51) International Patent Classification[7]: G01S 17/02, 17/89, 17/10, 7/481, H04N 7/18

(21) International Application Number: PCT/IL99/00490

(22) International Filing Date: 8 September 1999 (08.09.1999)

(25) Filing Language: English

(26) Publication Language: English

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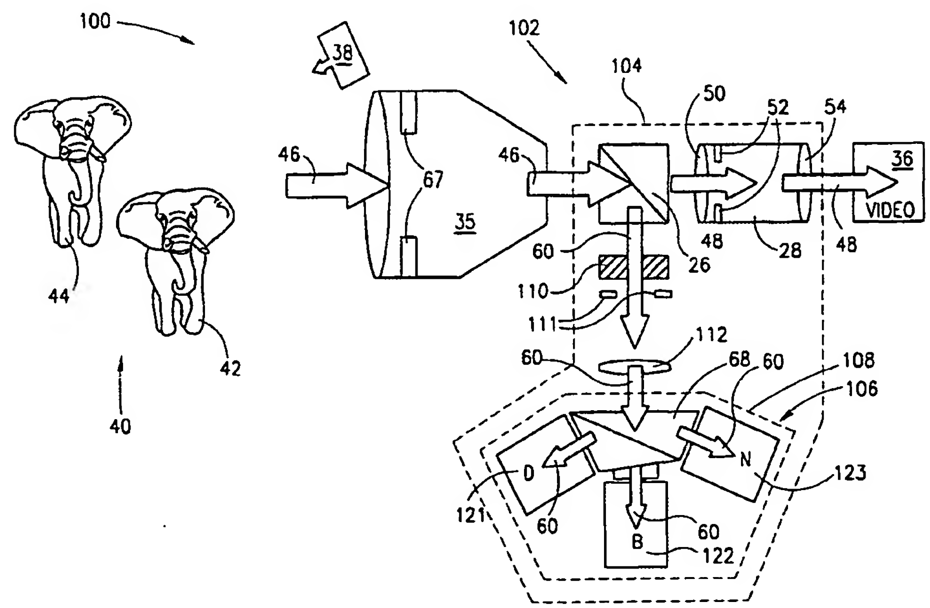
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: 3D IMAGING SYSTEM



(57) Abstract: An optical imaging system comprising: a taking lens system that collects light from a scene being imaged with the optical imaging system; a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light.

WO 01/18563 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

3D IMAGING SYSTEM

FIELD OF THE INVENTION

The invention relates to cameras that provide an image of a scene and measurements of distances to regions in the scene.

BACKGROUND OF THE INVENTION

3D cameras that provide distance measurements to objects and points on objects that they image are well known in the art. Gated 3D cameras comprise a photosensitive surface, such as a CCD or CMOS camera, hereinafter referred to as a "photosurface", and a gating means for gating the camera open and closed, such as an electro-optical shutter or a gated image intensifier. To image a scene and determine distances from the camera to objects in the scene, the scene is generally illuminated with a train of light pulses radiated from an appropriate light source. Generally, the radiated light pulses are infrared (IR) light pulses. For each radiated light pulse in the train, following an accurately determined delay from the time that the light pulse is radiated, the camera is gated open for a period of time, hereinafter referred to as a "gate". Light from the light pulse that is reflected from an object in the scene is imaged on the photosurface of the camera if it reaches the camera during the gate. Since the time elapsed between radiating a light pulse and the gate that follows it is known, the time it took imaged light to travel from the light source to the reflecting object in the scene and back to the camera is known. The time elapsed is used to determine the distance to the object.

In some of these 3D cameras, only the timing between light pulses and gates is used to determine distance from the 3D camera to a region in the scene imaged on a pixel of the photosurface of the 3D camera. In others, the *amount* of light registered by the pixel during the time that the camera is gated open is also used to determine the distance. In 3D cameras in which the amount of light is used to determine distances to the imaged region, the amount of light registered on a pixel is sometimes corrected for reflectivity of the imaged region, dark current and background light. The accuracy of measurements made with these 3D cameras is a function of the rise and fall times and jitter of the light pulses and their flatness, and how fast the gating means can gate the camera open and closed.

Gated 3D cameras that determine distances to objects in a scene that they image responsive to amounts of light registered on pixels of photosurfaces comprised in the 3D cameras are described in PCT Publications WO 97/01111, WO 97/01112, and WO 97/01113, the disclosures of which are incorporated herein by reference.

A gated 3D camera as shown in WO 97/01111 comprises first and second homologous photosurfaces and a light source that illuminates a scene being imaged with the camera with a train of, preferably IR, light pulses. The first photosurface, hereinafter referred to as a "distance photosurface", is gated on with a short gate following the time that each light pulse in the pulse train is radiated. The portion of light from each light pulse in the pulse train that is reflected by a region of the scene and enters the 3D camera, which is registered on a pixel of the distance photosurface, is a function of the distance of the region from the pixel. The second photosurface, hereinafter referred to as a "normalization photosurface", is preferably not gated. The portion of light from each light pulse in the pulse train that is reflected by a region of the scene and enters the 3D camera, which is registered on a pixel of the normalization photosurface, is independent of the distance of the region from the pixel. The amount of light registered on the pixel is a measure of the total amount of light reaching the camera from the imaged region. An amount of reflected light registered on a pixel of the distance photosurface from all the light pulses in the pulse train is normalized to an amount of reflected light from all the light pulses registered on a corresponding pixel in the normalization photosurface. Normalized amounts of light are used to determine distances to regions in the scene.

US patent 5,434,612 to Nettleton, the disclosure of which is incorporated herein by reference, describes a gated 3D camera comprising first, second and third photosurfaces. A scene imaged with this camera is not illuminated with a train of light pulses but with a single light pulse from a laser and the three photosurfaces are gated with respect to the time that the light pulse is radiated. The first photosurface is a distance photosurface. It is gated with a short gate so that a portion of the light pulse reflected by a region of the scene that is collected by the camera and registered on a pixel of the photosurface is a function of the distance of the region from the pixel. The second photosurface is a normalization photosurface. It is gated with a long gate so that the amount of reflected laser light registered on a pixel of the photosurface from an imaged region is a measure of the total amount of light reaching the camera from the imaged region. The third photosurface is used to measure background light by measuring the amount of light reaching the camera in a band of wavelengths near to wavelengths of light radiated by the laser. A filter that transmits light in the band of wavelengths close to the wavelength of the laser light but blocks light having a wavelength the same as a wavelength of light radiated by the laser shields the third photosurface. The third photosurface is gated simultaneously with the normalization photosurface by a long gate having a same gate width as the gate that gates the

second photosurface. A photosurface used to measure background light is hereinafter referred to as a "background photosurface".

Amounts of light registered on the background photosurface are used to correct the amounts of light registered on pixels of the distance and normalization photosurfaces for background light. Background corrected amounts of light registered by pixels on the normalization photosurface are used to normalize background corrected amounts of light registered by pixels on the distance photosurface. Distances to regions in the scene are determined from the background corrected normalized amounts of light registered by pixels on the distance photosurface.

Generally photosurfaces used in 3D cameras are gated by an external fast shutter. Certain types of CCD cameras allow for gating image acquisition on and off during a frame by turning the photosurfaces on and off. However, turn-on and turn-off times of these photosurfaces are generally much too long to enable gating the photosurfaces for the purposes of accurate distance measurements by turning them on and off. Typically turn-on and turn-off times for CCD photosurfaces are on the order of microseconds while gating for accurate distance measurements requires turn-on and turn-off times on the order of nano-seconds or less.

An electro-optical shutter suitable for use in 3D cameras, such as those described in the cited patent and patent applications is described in PCT Publication WO 99/40478, the disclosure of which is incorporated herein by reference.

Generally, a 3D camera is used in conjunction with an imaging camera, such as a video camera, that provides an image, hereinafter referred to as a "picture", of a scene being imaged with the 3D camera responsive to visible light from the scene. The 3D camera provides a "depth map" of the scene while the imaging camera provides a picture of the scene. Distances provided by the depth map are associated with visible features in the picture. In some applications distances associated with a picture of a scene are used to "window" the scene and remove unwanted features and/or objects in the scene, such as for example a background, from the picture. Such applications are described in PCT publication in WO 97/01111 cited above.

PCT patent application PCT/IL98/00476, entitled "Distance Measurement with a Camera", by some of the same inventors as the inventors of the present invention, the disclosure of which is incorporated herein by reference, describes a photosurface comprising pixels each of which has its own circuit that is controllable to gate the pixel on or off. A single photosurface of this type is useable to simultaneously provide the functions of a distance, background and normalization photosurface of a 3D camera as well as an imaging camera.

However, as the number of functions that the photosurface performs increases, the resolution of the photosurface decreases.

It is advantageous to have a simple robust optical system comprising a 3D camera and an imaging camera that is easily adjustable to simultaneously optimize quantities of light available from a scene imaged by the system that reach the cameras.

SUMMARY OF THE INVENTION

An aspect of some preferred embodiments of the present invention relates to providing an improved optical system, hereinafter referred to as a "3D imager", comprising a 3D camera and an imaging camera, for acquiring depth maps and pictures of a scene.

An aspect of some preferred embodiments of the present invention relates to providing a 3D imager that is relatively easily adjusted so that its 3D and imaging cameras may simultaneously receive optimum amounts of light available from a scene being imaged with the 3D imager.

An aspect of some preferred embodiments of the present invention relates to providing a 3D imager comprising an improved gating system for gating photosurfaces comprised in its 3D camera.

A 3D imager, in accordance with some preferred embodiments of the present invention, comprises a single taking lens boresighted with a gated 3D camera and an imaging camera. Preferably, the imaging camera is a color camera. Preferably the 3D camera comprises three photosensitive surfaces, a distance photosurface, a normalization photosurface and a background photosurface. Preferably, the 3D imager is used with a pulsed IR light source that illuminates a scene being imaged with the 3D imager with a train of preferably IR, light pulses. Light from the light pulses reflected by objects in the scene is used by the 3D camera to provide a depth map of the scene. Visual light from the scene is used by the imaging camera to provide a picture of the scene

While there is usually more than ample amount of visible light available to form a quality picture of the scene, the quantity of light available for the purpose of providing a depth map of the scene is usually small. As a result, the 3D imager usually requires that the taking lens be set to a much higher f-number to produce a quality picture of the scene than an f-number required to provide accurate distance measurements to the scene.

To provide proper control of the amounts of light reaching the 3D camera and the imaging camera, the 3D imager comprises a system that controls the amount of light reaching

the imaging camera from the taking lens independently of the amount of light reaching the 3D camera.

Preferably, the 3D camera comprises at least two irises. A first iris of the at least two irises controls the amount of visible light collected by the taking lens that reaches the imaging camera. A second iris controls either the amount of IR light collected by the taking lens that reaches the 3D camera or the total amount of IR and visible light collected by the taking lens that enters the 3D imager. As a result, the 3D imager can be adjusted to control independently amounts of light reaching the imaging camera and the 3D camera from a scene being imaged with the 3D imager. Therefore, subject to a level of illumination of the scene, a 3D imager, in accordance with a preferred embodiment of the present invention, is adjustable to simultaneously optimize the amounts of light from the scene that reach its 3D and imaging cameras.

In accordance with some preferred embodiments of the present invention all photosurfaces comprised in the 3D camera are gated with a same single fast shutter. This substantially simplifies the construction and control of the 3D imager. Preferably the 3D camera comprises three photosurfaces, a distance photosurface, a background photosurface and a normalization photosurface. The three photosurfaces are independently controllable to be turned on and off. Preferably, all light transmitted from the taking lens to the 3D camera passes through the single fast shutter. After passing through the shutter, portions of the light are directed to each of the three photosurfaces, for example by a prism. Preferably, the prism is a totally internal reflection (TIR) prism. At any given time, to determine which of the photosurfaces is gated by the fast shutter, all photosurfaces except a photosurface that is to be gated by the fast shutter are shut off.

It is to be noted that whereas the photosurfaces are controllable to be turned on or off, the speed with which a photosurface can be switched between on and off states is generally not fast enough to gate the photosurfaces for the purposes of accurate distance measurements. Therefore, for 3D cameras, gating photosurfaces by turning them on and off is generally not practical.

In some preferred embodiments of the present invention, the 3D camera and associated optical components are housed as a single unit, hereinafter referred to as a "3D module". The 3D module comprises portals for optically coupling a taking lens and imaging camera to the 3D module using methods and techniques known in the art. In some preferred embodiments of the

present invention, the 3D camera, imaging camera and associated electrical and optical components are integrated together as a single unit to which a taking lens is optically coupled.

There is therefore provided, in accordance with a preferred embodiment of the present invention an optical imaging system comprising: a taking lens system that collects light from a scene being imaged with the optical imaging system; a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light.

Preferably, the 3D camera and the imaging camera are boresighted with the taking lens system. Additionally or alternatively, the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are preferably homologous.

In some preferred embodiments of the present invention, an optical imaging system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera. Preferably, the light controller comprises an iris. Alternatively, the light controller preferably comprises a neutral density filter.

In some preferred embodiments of the present invention, an optical imaging system comprises a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system. Preferably, the light controller comprises an iris.

In some preferred embodiments of the present invention, an optical imaging system comprises a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera. Preferably, the light controller comprises an iris.

The 3D camera in an optical imaging system in accordance with some preferred embodiment of the present invention is a gated 3D camera. Preferably, the optical imaging system comprises a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the optical imaging system. Preferably, the pulsed light source radiates IR light.

According to some preferred embodiments of the present invention, the 3D camera comprises at least 2 photosurfaces. Preferably, the 3D camera comprises a light guide that receives light from the taking lens system and directs portions of the light that it receives to

each of the at least two photosurfaces. Preferably, the 3D camera comprises a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

The optical imaging system preferably comprises a controller that gates the single shutter open and closed. Preferably, the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon. Preferably, the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

Preferably, the at least two photosurfaces comprises three photosurfaces. Preferably, following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

Following a time that at least one light pulse in the train of light pulses is radiated, the controller preferably gates on the single shutter for a second gate and activates a second one of the photosurfaces and the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

Prefeably, following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

In some preferred embodiments of the present invention the light guide of the 3D camera is a three-way prism.

Some optical imaging systems in accordance with preferred embodiments of the present invention comprise a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

In some preferred embodiments of the present invention the light guide of the 3D camera is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

In some preferred embodiments of the present invention the imaging camera comprises a color camera.

In some optical imaging systems, in accordance with preferred embodiments of the present invention, the imaging camera is a color camera comprising separate R, G and B photosurfaces and the imaging system comprises a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

There is further provided in accordance with a preferred embodiment of the present invention a gated 3D camera comprising: a taking lens system that collects light from a scene imaged with the 3D camera; at least 2 photosurfaces; a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces; and a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

Preferably, the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon. Preferably, each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces. Preferably, the at least two photosurfaces comprises three photosurfaces.

The 3D camera preferably comprises a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the 3D camera. Prefereably, following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

Preferably, following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

Preferably, following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

BRIEF DESCRIPTION OF FIGURES

The invention will be more clearly understood by reference to the following description of preferred embodiments thereof read in conjunction with the figures attached hereto. In the

figures, identical structures, elements or parts which appear in more than one figure are labeled with the same numeral in all the figures in which they appear. Dimensions of components and features shown in the figures are chosen for convenience and clarity of presentation and are not necessarily shown to scale. The figures are listed below.

Fig. 1 schematically shows a 3D imager comprising a 3D module, in accordance with a preferred embodiment of the present invention;

Fig. 2A schematically shows a 3D imager comprising a 3D module, in accordance with a preferred embodiment of the present invention;

Fig. 2B shows a timing diagram for shuttering photosurfaces comprised in the 3D imager shown in Fig. 2A, in accordance with a preferred embodiment of the present invention;

Fig. 3 schematically shows a 3D imager comprising a 3D module, in accordance with a preferred embodiment of the present invention; and

Fig. 4 schematically shows a 3D imager comprising a 3D module and color imager integrated in a single unit, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 schematically shows a 3D imager 20 comprising a 3D module 22, in accordance with a preferred embodiment of the present invention, shown inside dashed boundary 24. 3D module 22 comprises a beam splitter 26, two refocusing lens systems 28 and 30, referred to as "refocusers" 28 and 30, and a 3D camera 32 having components shown inside a dashed boundary 34. 3D module 22 is coupled to a taking lens system 35 and an imaging camera 36, which is shown by way of example as a video camera. Preferably, video camera 36 is a color video camera. Taking lens 35 and video camera 36 may be any suitable taking lens and video camera, for example a CCD or CMOS camera, readily available on the commercial market. A pulsed light source 38 radiates pulse trains of, preferably IR light pulses, to illuminate scenes being imaged with 3D imager 20. 3D imager 20 is shown, by way of example, imaging a scene 40 having two elephants 42 and 44.

Visual light and IR light from IR source 38 that is reflected from scene 40 and collected by taking lens 35 is represented by large arrows 46. Collected light 46 is transmitted by taking lens 35 to beam splitter 26. Visual light, represented by arrows 48, in collected light 46, is transmitted by beam splitter 26 and enters refocuser 28. Refocuser 28 generally comprises a field lens 50, an iris 52 and a relay lens 54. Refocuser 28 is boresighted with taking lens 35 and preferably positioned so that an image of scene 40 formed by taking lens 35 from visual light 48 is located substantially at the location of field lens 50. Light from field lens 50 passes

through iris 52 and continues towards relay lens 54, which transmits the light to video camera 36. Video camera 36 is boresighted with refocuser 28 and taking lens 35. The amount of light received by video 36 from refocuser 28 is controlled by iris 52. Received visual light 48 is imaged by video 36 to form a picture of scene 40.

IR light, represented by dashed arrows 60, in collected light 46 that is incident on beam splitter 26 is reflected by beam splitter 26 to refocuser 30, which is boresighted with taking lens 35. Refocuser 30 is generally similar to refocuser 28 and preferably comprises a field lens 62, an iris 64 and a relay lens 66. Refocuser 30 is preferably positioned so that an image of scene 40 formed in IR light 60 by taking lens 35 is located at the location of field lens 62. Refocuser 30 transmits IR light that it receives towards 3D camera 32 which is boresighted with refocuser 30 and taking lens 35. The amount of IR light 60 transmitted by refocuser 30 to 3D camera 32 is controlled by iris 64.

Irises 52 and 64 are controllable independently of each other and therefore enable the amounts of IR and visual light reaching 3D camera 32 and video camera 36 respectively to be controlled independently of each other, in accordance with a preferred embodiment of the present invention. 3D imager 20 therefore can easily be adjusted to simultaneously optimize the amounts of IR light reaching 3D camera 32 and visual light reaching video camera 36 from taking lens 35 to provide simultaneous quality depth maps and pictures of scene 40.

It is to be noted that commercially available taking lenses are generally supplied with an iris and taking lens 35 is shown with an iris 67. In operation of 3D imager 20, iris 67 is preferably permanently set to maximum open and the amounts of light reaching 3D camera 32 and video camera 36 are controlled by irises 64 and 32 respectively. However, in some preferred embodiments of the present invention iris 67 is used in place of one of irises 52 or 64. For example, generally a greater fraction of IR light collected by taking lens 35 is needed to produce a quality depth map of a scene than the fraction that is needed of visible light collected by taking lens 35 to provide a quality picture of the scene. As a result, iris 67 may conveniently be used in place of iris 64 to modulate IR light reaching 3D camera 32.

3D camera 32 preferably comprises a three-way prism 68 and preferably three photosurfaces 71, 72 and 73. Three-way prism 68 receives IR light 60 transmitted from refocuser 30 and directs portions of the received IR light to each of photosurfaces 71, 72 and 73. Photosurfaces 71, 72 and 73 are respectively shuttered by fast shutters 81, 82 and 83. Fast shutters 81, 82 and 83, and fast shutters in other preferred embodiments of the present invention, are preferably either gated image intensifiers or fast solid state shutters of a type

described in above cited PCT patent application PCT/IL98/00060. In some preferred embodiments of the present invention in which 3D photosurfaces are shuttered individually by their own fast shutters, as are photosurfaces 71, 72 and 73, the shutters are comprised in the photosurfaces. Photosurfaces that comprise shuttering apparatus are described in PCT patent application PCT/IL98/00476 cited above. A controller (not shown) controls shutters 81, 82 and 83.

Photosurfaces 71, 72 and 73 function respectively as a distance photosurface, a background photosurface and a normalization photosurface and are labeled accordingly "D", "N" and "B" in Fig 1. The choice of which photosurface 71, 72 or 73 is a distance, background or normalization photosurface is arbitrary and the choices shown in Fig. 1 are choices of convenience. The controller controls shutters 81, 82 and 83 to gate photosurfaces 71, 72 and 73 following each IR pulse radiated by IR source 38 with a sequence of gates similar to prior art gate sequences used in gated 3D cameras. Prior art gating sequences are described in above cited references PCT Publications WO 97/01111, WO 97/01112, WO 97/01113, US Patent 5,434,612 and PCT Application PCT/IL98/00476.

Whereas, in the preceding paragraph it is implied that photosurfaces 71, 72 and 73 are similar or substantially identical, and this is generally the case, in some preferred embodiments of the present invention, different ones of the photosurfaces in 3D camera 32 are different. For example, a photosurface used to measure background light or normalization light may have a lower resolution than a resolution of a photosurface used as a distance photosurface and this can be advantageous.

Shutter 81 is controlled to respectively gate distance photosurface 71 with a relatively short gate and normalization photosurface 73 with a relatively long gate. Preferably the short gate has a gate width that is equal to the pulse width of IR pulses radiated by pulsed IR source 38. Preferably the time centers of the short gates and long gates coincide. The controller preferably controls shutter 83 to gate background photosurface 72 with a short gate. The short gate of background photosurface 72 is timed to occur when no IR light from pulsed IR source 38 that is reflected from scene 40 is incident on taking lens 35. Preferably the short gates of distance photosurface 71 and background photosurface 72 are equal. During the short gate of background photosurface 72, substantially only background light and dark current effects are registered by background photosurface 72.

The amounts of light registered on pixels of distance photosurface 71, background photosurface 72 and normalization photosurface 73 are sensed and transmitted to a processor

(not shown) using methods known in the art and processed as in prior art to provide a depth map of scene 40.

Photosurfaces comprised in 3D cameras and imaging cameras that are used in 3D imagers, in accordance with preferred embodiments of the present invention, are preferably homologous. Two photosurfaces are said to be homologous if there is a one to one mapping of regions of one of the photosurfaces onto the other and the positions of any two regions that map onto each other are similar in their respective photosurfaces.

Fig. 2 shows another 3D imager 100 imaging scene 40. 3D imager 100 comprises a 3D module 102 optically coupled to taking lens 35 and video camera 36.

3D module 102, having components shown inside dashed boundary 104, is similar to 3D module 22. 3D module 102 comprises beam splitter 26 and refocuser 28 that transmits visual light 48 from taking lens 35 to video camera 36, which generates a picture of scene 40 responsive to the visual light that it receives. 3D module 102 comprises a 3D camera 106 having components shown inside dashed boundary 108.

However, unlike 3D module 22, 3D module 22 does not comprise a refocuser 30 that irises and transmits IR light from beam splitter 26 to 3D camera 106. Instead, IR light 60 from beam splitter 26 passes through a fast shutter 110 and a relay lens 112 that directs the IR light to 3D camera 106. Preferably, an iris 111 controls the amount of light from taking lens 35 transmitted to 3D camera 106. 3D camera 106 is similar to 3D camera 32 shown in Fig. 1 and comprises a three-way prism 68 that directs portions of IR light 60 incident on three-way prism 68 to a distance photosurface 121, a background photosurface 122 and a normalization photosurface 123. However, unlike photosurfaces 71, 72 and 73 in 3D camera 32, Photosurfaces 121, 122 and 123 are not individually gated by their own fast shutters as are photosurfaces 71, 72 and 73 in 3D camera 32. Fast gating for all photosurfaces 121, 122 and 123 is done by fast shutter 110, which is common to all photosurfaces 121, 122 and 123. Photosurfaces 121, 122 and 123 are turned on and off to determine which photosurface registers light during a gate of fast shutter 110. Preferably, only one photosurface is turned on during a gate of fast shutter 110.

Fast shutter 110 is controlled by a controller (not shown) to be gated open with a sequence of short and long gates in synchrony with IR pulses radiated by IR source 38. Preferably, two sequential short gates having a same gate width follow every other IR light pulse in a train of light pulses radiated by IR light source 38 to illuminate scene 40. Preferably, a long gate follows every IR pulse that is not followed by the two sequential short gates.

During the first short gate, IR light reflected from scene 40 is collected by taking lens 35 and transmitted to 3D camera 106 and only distance photosurface 121 is turned on. Only distance photosurface 121 registers amounts of light incident on 3D camera 106 during the first short gate. The amount of reflected IR light registered on distance photosurface 121 from a region of scene 40, compared to the total amount of reflected IR light reaching taking lens 35 from the region is useable to determine the distance of the region from 3D camera 106.

The timing of the first short gate with respect to an IR light pulse from which reflected light is registered by distance photosurface 121 and the gate width of the short gate, determine a center for a range of distances for which 3D camera 106 can provide distance measurements to regions in scene 40. The width of the range is determined by the pulse width of the IR pulses and the gate width of the short gate.

The second short gate is timed to occur when no IR light reflected from scene 40 reaches taking lens 35. During the second short gate only background light is collected by taking lens 35 and transmitted to 3D camera 106. Only background photosurface 122 is turned on and registers light incident on 3D camera 106. Background photosurface 106 exclusively acquires background light information from scene 40.

The time centers of the long gates and the first short gates are preferably delayed by the same time with respect to their respective IR light pulses. During the long gates, only normalization photosurface 123 is turned on. Normalization photosurface 123 registers amounts of IR light that are responsive to total amounts of reflected IR light reaching taking lens 35 from regions of scene 40.

It should be noted that, while photosurfaces 121, 122 and 123 are turned on and off to gate 3D camera 106, gating of 3D camera 106 for accurate distance measurements cannot be accomplished without fast gate 110 and only by turning on and off photosurfaces 121, 122 and 123. Accurate distance measurement require that photosurfaces 121, 122 and 123 be gated on and off in times on the order of nanoseconds or less. Photosurfaces such as CCD photosurfaces can generally be turned on and off in times on the order of microseconds.

However, whereas turning photosurfaces on and off can not generally be used for fast shuttering of photosurfaces, it can be used for irising photosurfaces. For example, a photosurface in some video cameras can be turned off for a fraction of a frame time to control an amount of light that the photosurface registers. In some preferred embodiments of the present invention irising of an imaging camera is accomplished by controlling the length of time that a photosurface comprised in the imaging camera is on during a frame time.

As in prior art, amounts of light registered on pixels of distance photosurface 121 are corrected for background and normalized using amounts of light registered on corresponding pixels of on background photosurface 122 and normalization photosurface 123. The corrected and normalized amounts of light are used to determine distances to reflecting regions of scene 40, in this case, by way of example distances to elephants 42 and 44.

Fig. 2B shows, as function of time, a graph 130 of gates of fast shutter 110 and associated periods of time, hereinafter referred to as "on times" during which photosurfaces 121, 122 and 123 are turned on, in accordance with a preferred embodiment of the present invention. The gates and on times are shown by way of example synchronized with four IR pulses, represented by rectangles 131, 132, 133 and 134 on a time line 136, of a pulse train of IR pulses radiated by IR source 38 shown in Fig. 2A to illuminate scene 40. The choice of four IR pulses in the train of pulses is by way of example only and is a choice of convenience.

The gates of fast gate 110 are represented by dashed rectangles 141, 142 and 143. Gates 141 are short "distance gates" and gates 142 are short "background gates". A distance gate 141 and a background gate 142 follow every other IR pulse (the odd numbered IR pulses in Fig. 2B) in the pulse train radiated by IR source 38. Gates 143 are long "normalization" gates that preferably follow every IR pulse (the even numbered IR pulses in Fig. 2B) that is not followed by a distance gate 141 and a background gate 142.

The on times of distance, background and normalization photosurfaces 121, 122 and 123 are shown as trapezoids 150 on timelines 151, 152 and 153 respectively. Distance photosurface 121 is on only during short distance gates 141. Background photosurface 122 is on only during short background gates 142 and normalization photosurface 123 is on only during long normalization gates 143. The sloped side edges of the trapezoids indicate the relatively long periods of time required to turn on and off a photosurface compared to the short turn-on and turn-off times required to gate photosurfaces quickly enough to provide accurate distance measurements.

An intensity of light received by taking lens 35 from elephant 42 as a function of time is represented by the height of an "intensity" line 160 above a base line 162. Rectangular "peaks" 164 in the height of intensity line 160 occur when IR light reflected from an IR pulse by elephant 42 reaches taking lens 35. The height of intensity line 160 outside of peaks 164 represents background light received from elephant 42. Amounts of light received from elephant 42 that are registered by photosurfaces 121, 122 and 123 during gates 141, 142 and 143 are represented by shaded areas 171, 172 and 173 respectively.

Similarly, an intensity of light received by taking lens 35 from second elephant 44 as a function of time is represented by the height of an intensity line 180, which has IR "reflection peaks" 184, above a base line 182. Shaded areas 181, 182, and 183 represent amounts of light from second elephant 44 registered by photosurfaces 121, 122 and 123 during gates 141, 142 and 143 respectively.

For elephant 42, background corrected light registered by distance photosurface 121 is represented by an area equal to the sum of the areas 171 minus the sum of areas 172. Background corrected light registered by normalization photosurface 123 is represented by an area equal to the sum of areas 173 minus the product of the ratio of the gate width of long gates 143 to the gate width of short gates 142 times the sum of areas 173. For elephant 44, background corrected light registered by distance photosurface 121 is represented by an area equal to the sum of areas 181 minus the sum of areas 182. Background corrected light registered by normalization photosurface 123 for elephant 44 is represented by an area equal to the sum of areas 183 minus the product of the ratio of the gate width of long gates 143 to the gate width of short gates 142 times the sum of areas 183.

Elephant 44 is further away from 3D imager 100 than elephant 42. As a result, the amount of background corrected light registered by distance photosurface 121 normalized to background collected light registered by normalization photosurface 123 is less for elephant 44 than for elephant 42.

Fig. 3 shows another 3D imager 200 imaging scene 40, in accordance with a preferred embodiment of the present invention.

Imager 200 comprises a 3D module 202 having components shown inside dashed border 204, which is coupled to taking lens 35 and video camera 36. 3D module 202 comprises a 3D camera 206 having components shown inside dashed border 208. 3D camera 206 comprises a four-way prism 210 that directs portions of IR light 60 in light 46 that is collected by taking lens 35 from scene 40 to distance, background and normalization photosurfaces 71, 72 and 73 respectively. Each of photosurfaces 71, 72 and 73 is gated by its own fast shutter 81, 82 and 83 respectively. Photosurfaces 71, 72 and 73 are gated similarly to the manner in which photosurfaces 71, 72 and 73 comprised in 3D camera 206, shown in Fig. 1, are gated. Amounts of IR light 60 collected by taking lens 35 that reaches 3D camera 206 is controlled by iris 67 comprised in taking lens 35.

Four-way prism 210 also directs visual light 48 in light 46 collected by taking lens 35 to a refocuser 28 that preferably comprises a field lens 50 an iris 52 and a relay lens 54. Refocuser 28 transmits visual light 48 that it receives from four-way prism 210 to video camera 36.

Fig. 4 schematically shows another 3D imager 220 imaging scene 40 in accordance with a preferred embodiment of the present invention. 3D imager 220 comprises a unit 222, hereinafter referred to as a "combination unit", having components located within a border 224. Combination unit 222 comprises a 3D camera 226 having components shown inside a dashed boundary 228 and three color cameras, a Red (R) camera 230 a Green (G) camera 232 and a Blue (B) camera 234. Combination unit 222 is coupled to a taking lens 35, which is boresighted with 3D camera 226 and color cameras 230, 232 and 234.

Combination unit 222 comprises a four-way prism 236 that directs visual light 48 collected by taking lens 35 to each of color cameras 230, 232 and 234 and IR light 60 collected by taking lens 35 to a fast shutter 110 that shutters 3D camera 226. Preferably, combination unit 222 comprises an iris 111 that controls the amount of light 60 transmitted from taking lens 35 to 3D camera 226. IR light 60 that fast shutter 110 transmits is incident on a relay lens 238 that relays the light to a three-way prism 68, which directs portions of the IR light 60 that it receives to a distance photosurface 121, a background photosurface 122 and a normalization photosurface 123. 3D camera 226 is substantially the same as 3D camera 106 shown in Fig. 2A and is gated by controlling fast shutter 110 and photo surfaces 121, 122, and 123 in the same manner in which 3D camera 106 is gated.

Whereas combination unit 222 is shown comprising a 3D camera in which all the photosurfaces are shuttered by single shutter, in some preferred embodiments of the present invention, combination unit 222 comprises a 3D camera similar to 3D camera 32 shown in Fig. 1 in which each photosurface of the 3D camera is shuttered by its own shutter.

Combination unit 222 preferably comprises an adjustable neutral density filter 240 located between taking lens 35 and four-way prism 236. Neutral density filter 240 is chosen so that it does not substantially attenuate IR light. Neutral density filter 240 is used to control the amount of visible light 48 collected by taking lens 35 that reaches color cameras 230, 232 and 234. The amount of IR light 60 reaching 3D camera 226 is controlled by iris 67 comprised in taking lens 35.

In the description and claims of the present application, each of the verbs, “comprise” “include” and “have”, and conjugates thereof, are used to indicate that the object or objects of

the verb are not necessarily a complete listing of components, elements or parts of the subject or subjects of the verb.

The present invention has been described using detailed descriptions of preferred embodiments thereof that are provided by way of example and are not intended to limit the scope of the invention. The described preferred embodiments comprise different features, not all of which are required in all embodiments of the invention. Some embodiments of the present invention utilize only some of the features or possible combinations of the features. Variations of embodiments of the present invention that are described and embodiments of the present invention comprising different combinations of features noted in the described embodiments will occur to persons of the art. The scope of the invention is limited only by the following claims.

CLAIMS

1. An optical imaging system comprising:

a taking lens system that collects light from a scene being imaged with the optical imaging system;

a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and

an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light.

2 An optical imaging system according to claim 1 wherein the 3D camera and the imaging camera are boresighted with the taking lens system.

3. An optical imaging system according to claim 1 or claim 2 wherein the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are homologous.

4. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera.

5. An optical imaging system according to claim 4 wherein the light controller comprises an iris.

6. An optical imaging system according to claim 4 wherein the light controller comprises a neutral density filter.

7. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system.

8. An optical imaging system according to claim 7 wherein the light controller that controls the amount of light collected by the taking lens system that enters the imaging system comprises an iris.

9. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera.

10. An optical imaging system according to claim 9 wherein the light controller that controls the amount of light from the taking lens system that reaches the 3D camera comprises an iris.

11. An optical imaging system according to any of the preceding claims wherein the 3D camera is a gated 3D camera.

12. An optical imaging system according to claim 11 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the optical imaging system.

13. An optical imaging system according to claim 12 wherein the pulsed light source radiates IR light.

14. An optical imaging system according to any of claims 11 - 13 wherein the 3D camera comprises at least 2 photosurfaces.

15. An optical imaging system according to claim 14 wherein the 3D camera comprises a light guide that receives light from the taking lens system and directs portions of the light that it receives to each of the at least two photosurfaces.

16. An optical imaging system according to claim 15 and comprising a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

17. An optical imaging system according to claim 16 and comprising a controller that gates the single shutter open and closed.

18. An optical imaging system according to claim 17 wherein the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon.

19. An optical imaging system according to claim 18 wherein each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

20. An optical imaging system according to claim 19 wherein the at least two photosurfaces comprises three photosurfaces.

21. An optical imaging system according to claim 20 wherein following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and wherein the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

22. An optical imaging system according to claim 21 wherein following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and wherein the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

23. An optical imaging system according to claim 22 wherein following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and wherein the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

24. An optical imaging system according to any of claims 15 -23 wherein the light guide is a three-way prism.

25. An optical imaging system according to any of claims 1 - 24 and comprising a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

26. An optical imaging system according to any of claims 7 - 23 wherein the light guide is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

27. An optical imaging system according to any of the preceding claims wherein the imaging camera comprises a color camera.

28. An optical imaging system according to any of claims 1 - 24 wherein the imaging camera is a color camera comprising separate R, G and B photosurfaces and comprising a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

29. A gated 3D camera comprising:

a taking lens system that collects light from a scene imaged with the 3D camera;

at least 2 photosurfaces;

a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces; and

a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

30. A 3D camera according to claim 29 wherein the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon.

31. A 3D camera according to claim 30 wherein each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

32. A 3D camera according to claim 31 wherein the at least two photosurfaces comprises three photosurfaces.

33. A 3D camera according to claim 32 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the 3D camera.

34. A 3D camera according to claim 33 wherein following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and wherein the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

35. A 3D camera according to claim 34 wherein following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and wherein the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

36. A 3D camera according to claim 35 wherein following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and wherein the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

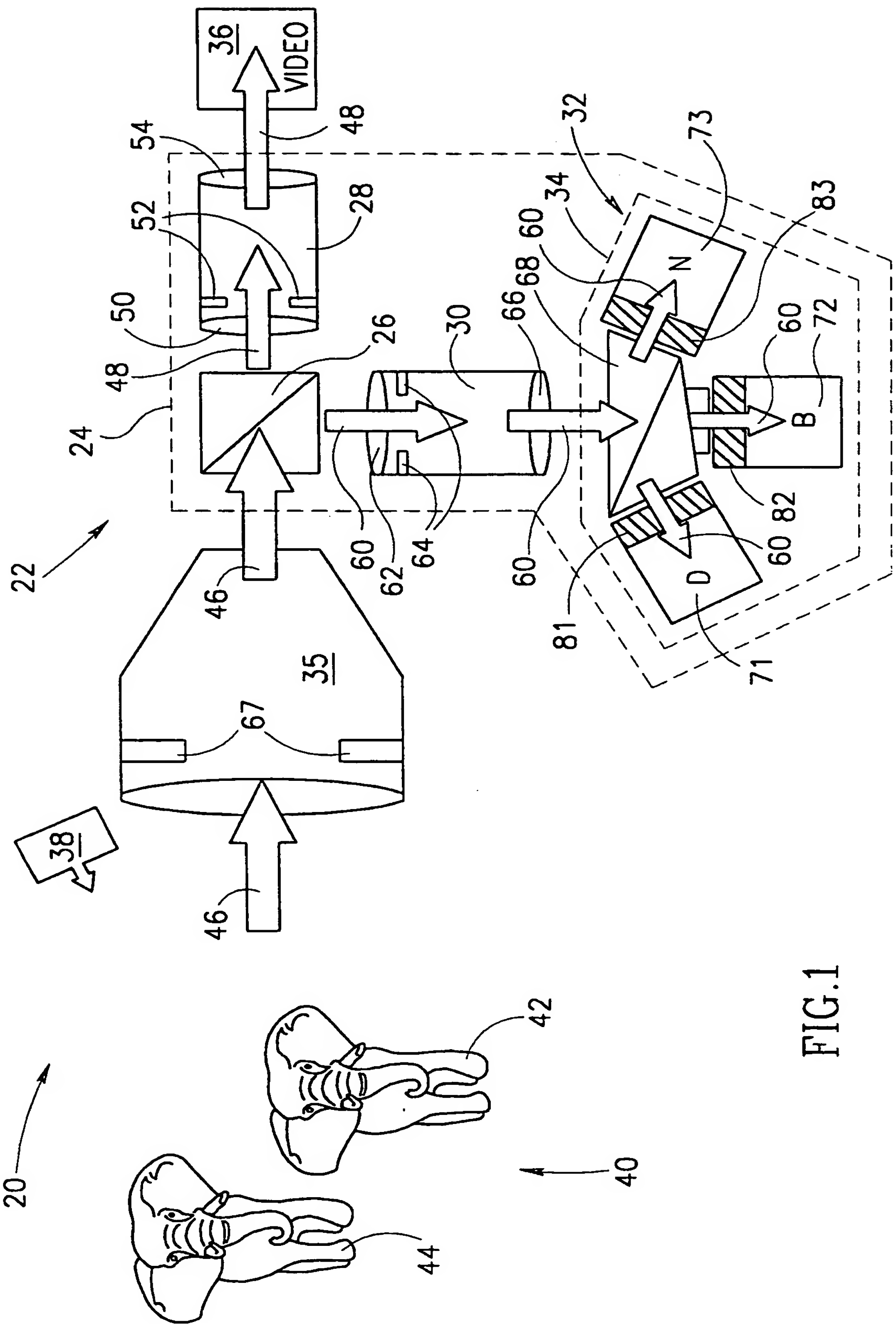

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FIG.1

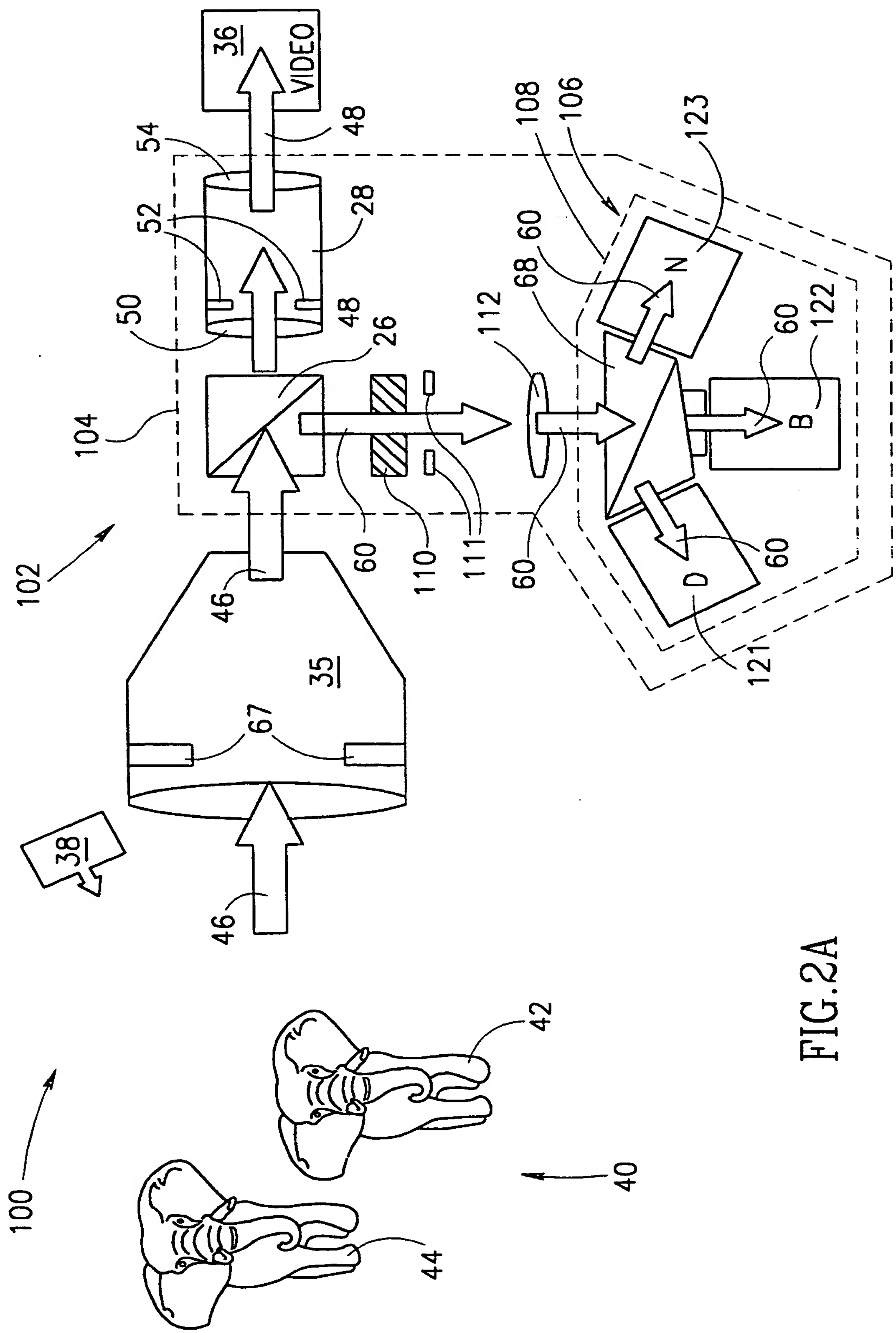
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FIG.2A

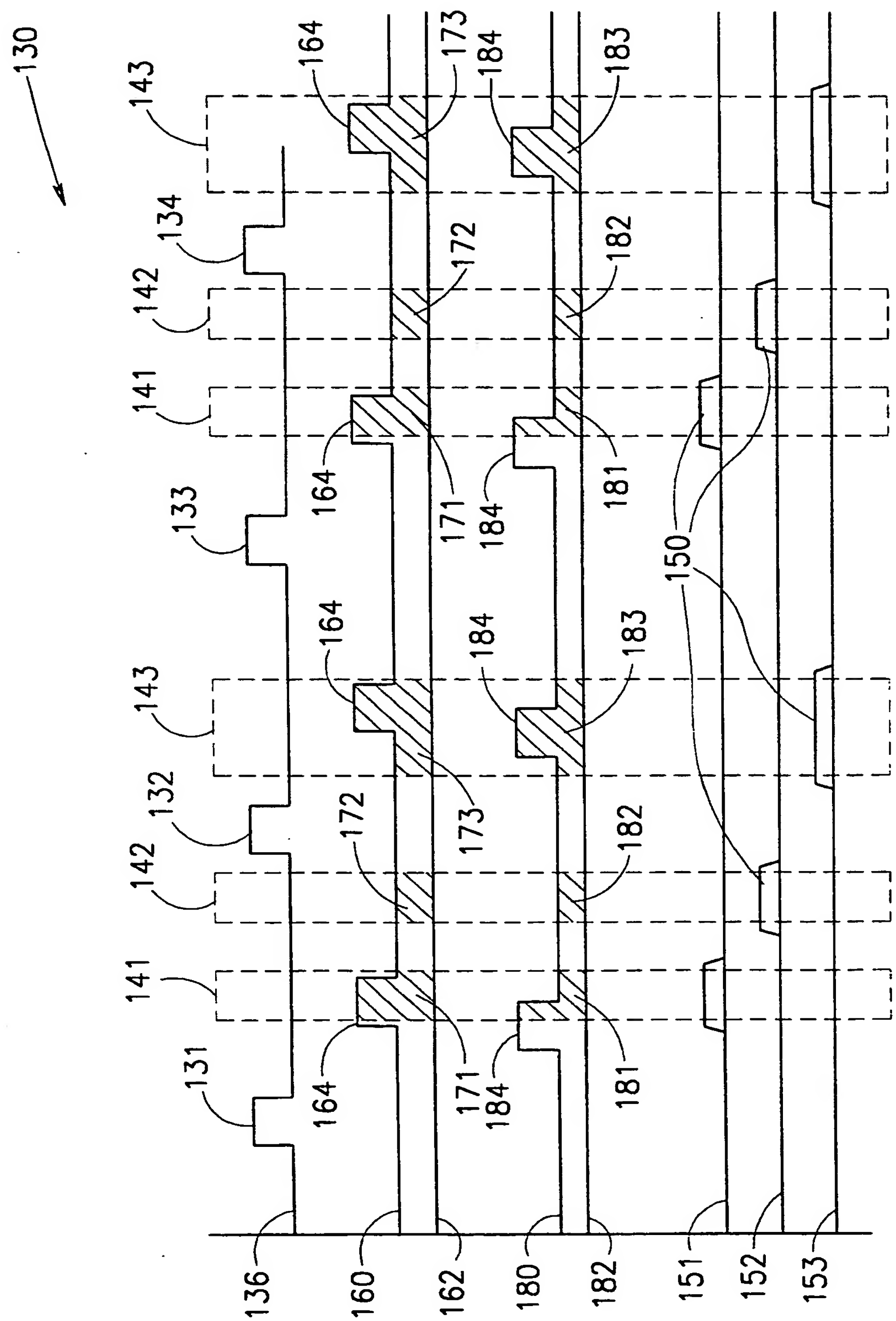
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FIG.2B

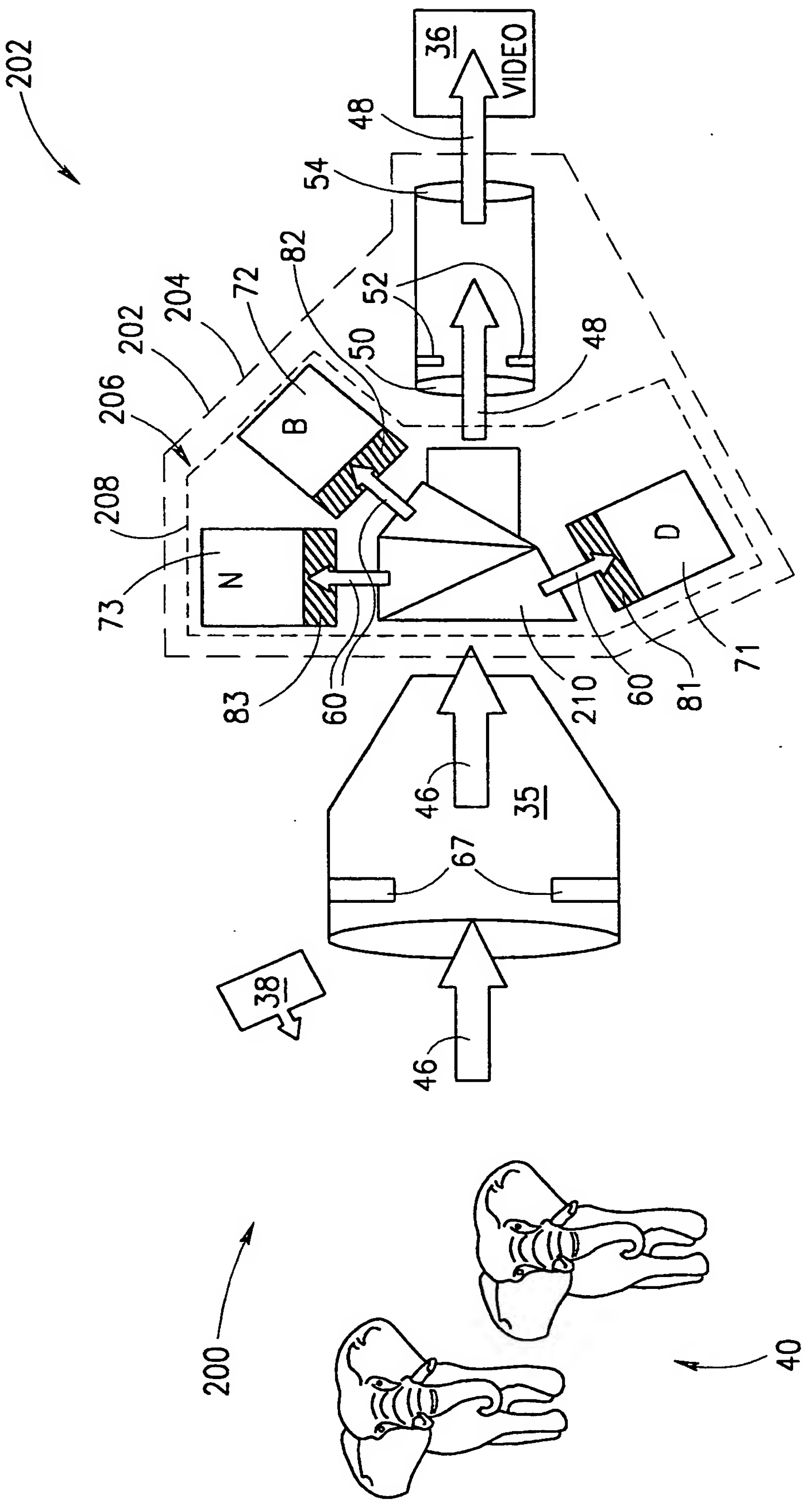
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FIG.3

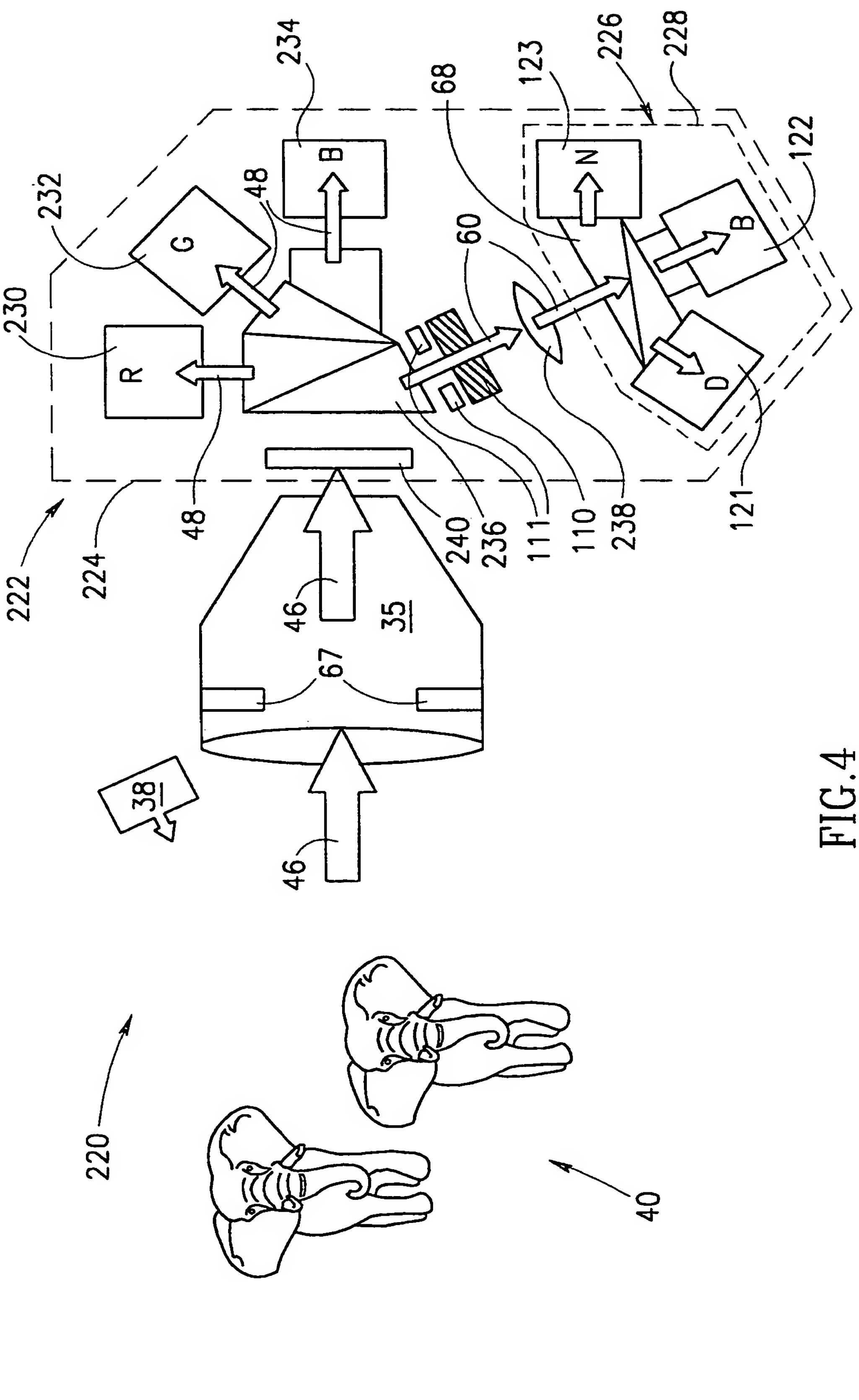
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FIG.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 99/00490

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S17/02 G01S17/89 G01S17/10 G01S7/481 H04N7/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01S H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 434 612 A (NETTLETON JOHN E ET AL) 18 July 1995 (1995-07-18) cited in the application column 4, line 51 -column 5, line 10; figure 6	1-4
Y	column 1 -column 2	5-20, 27-34
X	EP 0 777 134 A (YALESTOWN CORP NV) 4 June 1997 (1997-06-04)	1,11-13, 27
A	column 3, line 35 -column 6, line 40; figures 1-3	2-10, 14-28
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A	page 7, line 7 -page 8, line 4; figures 9-11 page 12, line 5 -page 14, line 17	35,36

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 May 2000	17/05/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Devine, J

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 198 657 A (TROST PETER K ET AL) 30 March 1993 (1993-03-30) the whole document	1-36
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A	WO 97 01113 A (YAHAV GIORA ;IDDAN GAVRIEL I (IL); 3DV SYSTEMS LTD (IL)) 9 January 1997 (1997-01-09) cited in the application the whole document	1-36
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Information on patent family members

International Application No
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Information on patent family members

International Application No
PCT/IL 99/00490

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Form PCT/ISA/210 (patent family annex) (July 1992)

CLAIMS

1. An optical imaging system comprising:

a taking lens system that collects light from a scene being imaged with the optical imaging system;

a 3D camera comprising at least one photosurface that receives light from the taking lens system simultaneously from all points in the scene and provides data for generating a depth map of the scene responsive to the light; and

an imaging camera comprising at least one photosurface that receives light from the taking lens system and provides a picture of the scene responsive to the light.

2 An optical imaging system according to claim 1 wherein the 3D camera and the imaging camera are boresighted with the taking lens system.

3. An optical imaging system according to claim 1 or claim 2 wherein the at least one photosurface of the 3D camera and the at least one photosurface of the imaging camera are homologous.

4. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the imaging camera without affecting the amount of light from the taking lens system that reaches the 3D camera.

5. An optical imaging system according to claim 4 wherein the light controller comprises an iris.

6. An optical imaging system according to claim 4 wherein the light controller comprises a neutral density filter.

7. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light collected by the taking lens system that enters the imaging system.

8. An optical imaging system according to claim 7 wherein the light controller that controls the amount of light collected by the taking lens system that enters the imaging system comprises an iris.

9. An optical imaging system according to any of the preceding claims and comprising a light controller adjustable to control the amount of light from the taking lens system that reaches the 3D camera without affecting the amount of light from the taking lens that reaches the imaging camera.

10. An optical imaging system according to claim 9 wherein the light controller that controls the amount of light from the taking lens system that reaches the 3D camera comprises an iris.

11. An optical imaging system according to any of the preceding claims wherein the 3D camera is a gated 3D camera.

12. An optical imaging system according to claim 11 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the optical imaging system.

13. An optical imaging system according to claim 12 wherein the pulsed light source radiates IR light.

14. An optical imaging system according to any of claims 11 - 13 wherein the 3D camera comprises at least 2 photosurfaces.

15. An optical imaging system according to claim 14 wherein the 3D camera comprises a light guide that receives light from the taking lens system and directs portions of the light that it receives to each of the at least two photosurfaces.

16. An optical imaging system according to claim 15 and comprising a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

17. An optical imaging system according to claim 16 and comprising a controller that gates the single shutter open and closed.

18. An optical imaging system according to claim 17 wherein the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon.

19. An optical imaging system according to claim 18 wherein each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

20. An optical imaging system according to claim 19 wherein the at least two photosurfaces comprises three photosurfaces.

21. An optical imaging system according to claim 20 wherein following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and wherein the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

22. An optical imaging system according to claim 21 wherein following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and wherein the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

23. An optical imaging system according to claim 22 wherein following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and wherein the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

24. An optical imaging system according to any of claims 15 -23 wherein the light guide is a three-way prism.

25. An optical imaging system according to any of claims 1 - 24 and comprising a beam splitter that receives light from the taking lens system and directs a portion of the received light towards the 3D camera and a portion of the received light to the imaging camera.

26. An optical imaging system according to any of claims 7 - 23 wherein the light guide is a four-way prism that receives light from the taking lens system and directs a portion of the received light to the imaging camera.

27. An optical imaging system according to any of the preceding claims wherein the imaging camera comprises a color camera.

28. An optical imaging system according to any of claims 1 - 24 wherein the imaging camera is a color camera comprising separate R, G and B photosurfaces and comprising a four way prism that receives light from the taking lens system and directs a portion of the received light to each of the R, G and B photosurfaces and to the single shutter of the 3D camera.

29. A gated 3D camera comprising:

a taking lens system that collects light from a scene imaged with the 3D camera;

at least 2 photosurfaces;

a light guide that receives light from the taking lens and directs portions of the light that it receives to each of the at least two photosurfaces; and

a single shutter, which when gated open enables light from the taking lens system to reach the light guide.

30. A 3D camera according to claim 29 wherein the controller controls each of the photosurfaces to be activated and deactivated and wherein when a photosurface is activated, it is sensitive to light incident thereon.

31. A 3D camera according to claim 30 wherein each time that the controller gates on the single shutter it activates one and only one of the at least two photosurfaces.

32. A 3D camera according to claim 31 wherein the at least two photosurfaces comprises three photosurfaces.

33. A 3D camera according to claim 32 and comprising a pulsed light source that radiates a train of light pulses to illuminate a scene being imaged with the 3D camera.

34. A 3D camera according to claim 33 wherein following a time that at least one light pulse is radiated, the controller gates on the single shutter for a first gate and turns on a first photosurface and wherein the first gate is timed so that light reflected from the at least one light pulse by a region in the scene is registered by the first photosurface.

35. A 3D camera according to claim 34 wherein following a time that at least one light pulse in the train of light pulses is radiated, the controller gates on the single shutter for a second gate and activates a second one of the photosurfaces and wherein the second gate is timed so that during the second gate no light from the at least one light pulse reflected by the region is registered by the second photosurface.

36. A 3D camera according to claim 35 wherein following a time that at least one light pulse in the train of light pulses is radiated the controller gates on the single shutter for a third gate and activates a third one of the photosurfaces and wherein the controller controls the gate width and timing of the third gate so that during the third gate substantially all light from the at least one pulse that is reflected by the region, which is collected by the taking lens system, is registered by the third photosurface.

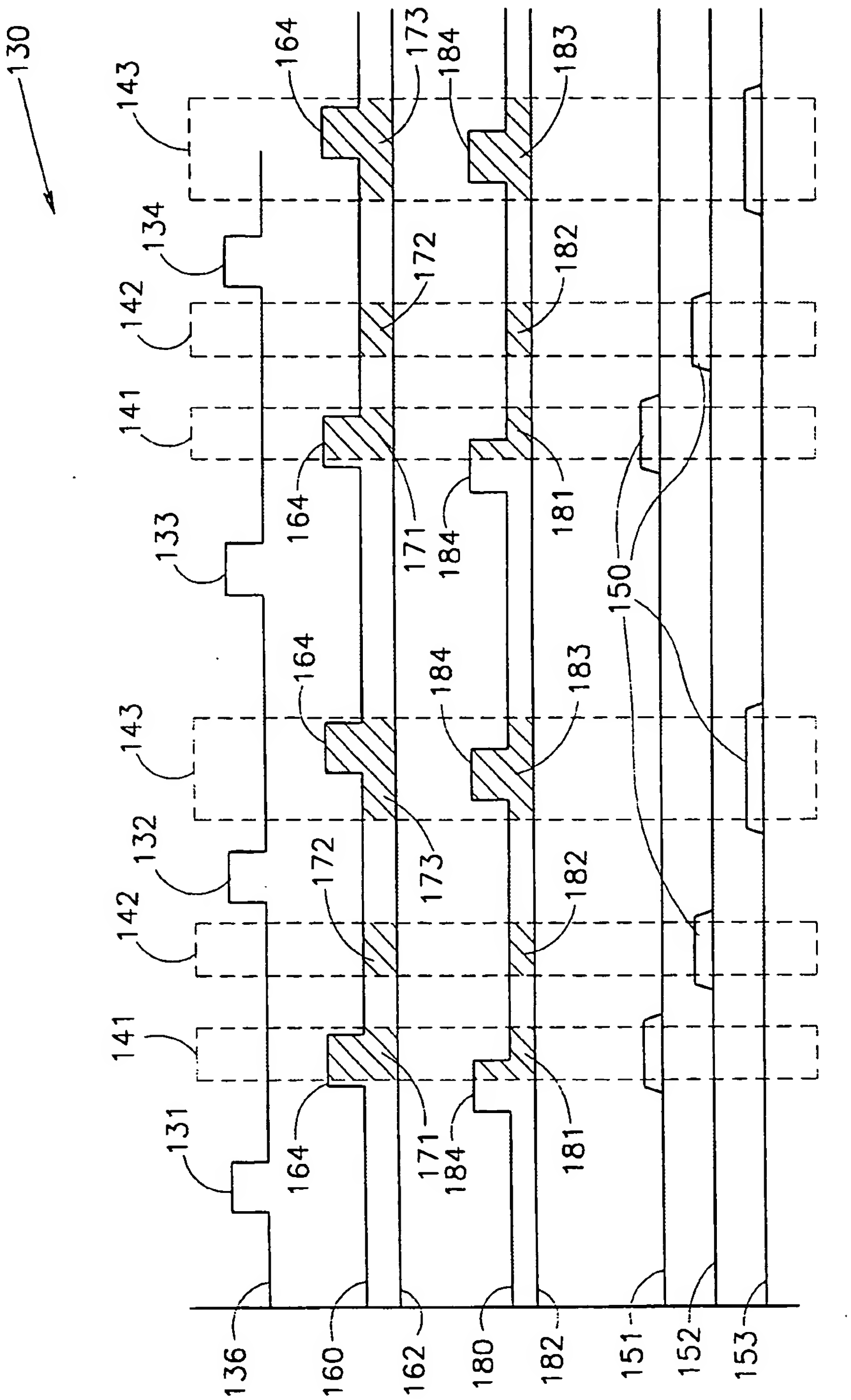
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FIG.2B